



Anholt offshore wind farm wake investigated from satellite data and wake models

Hasager, Charlotte Bay; Badger, Merete; Hansen, Kurt Schaldemose; Pena Diaz, Alfredo; Ott, Søren; Volker, Patrick; van der Laan, Paul; Ahsbahs, Tobias Torben

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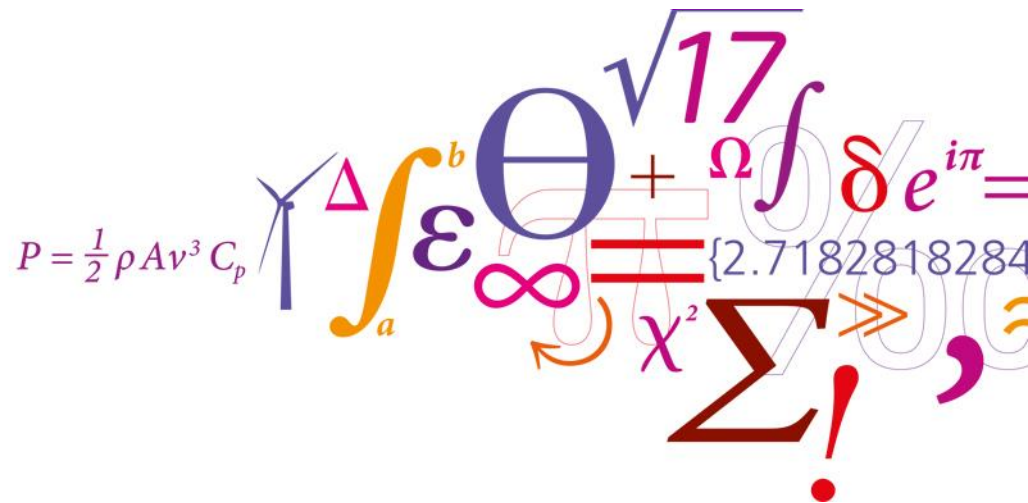
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Anholt offshore wind farm wake investigated from satellite data and wake models

Charlotte Hasager
 Merete Badger
 Kurt S. Hansen
 Alfredo Peña
 Søren Ott
 Patrick Volker
 Paul van der Laan
 Tobias Ahsbahs



Anholt offshore wind farm

Number of turbines: 111
Wind turbine capacity: 3.6 MW
Rotor diameter: 120 meters

Construction period: 2012-2013

SCADA data for analysis is from January 1st, 2013 to June 30, 2015 (2.5 years)

Courtesy: DONG Energy

Research question

How well can we quantify the wake effect from modelling and satellite?

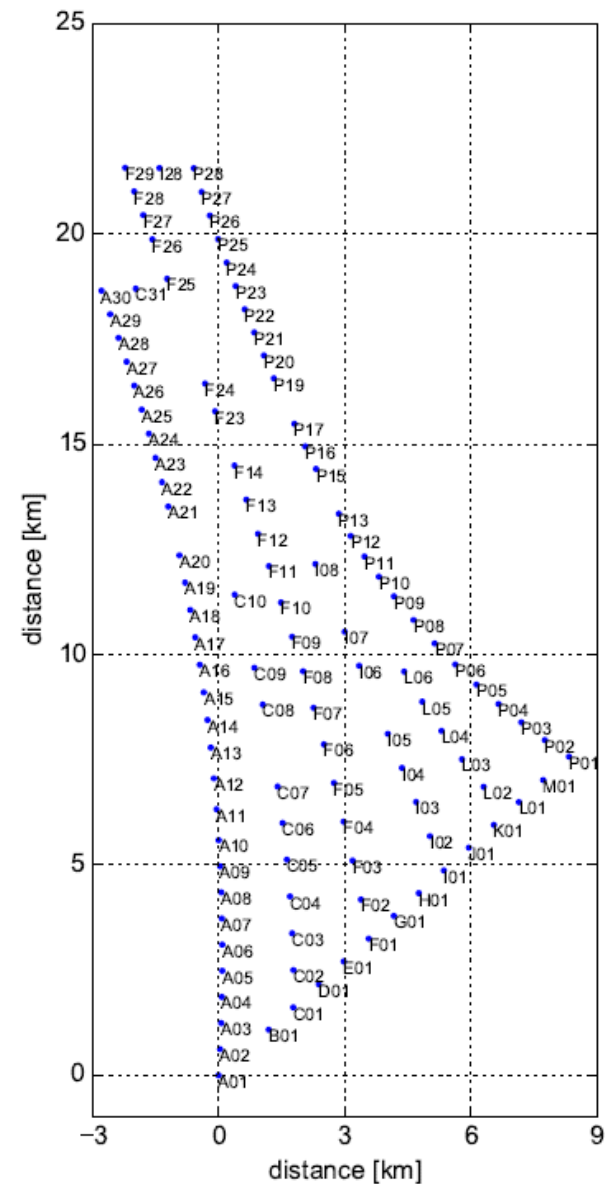
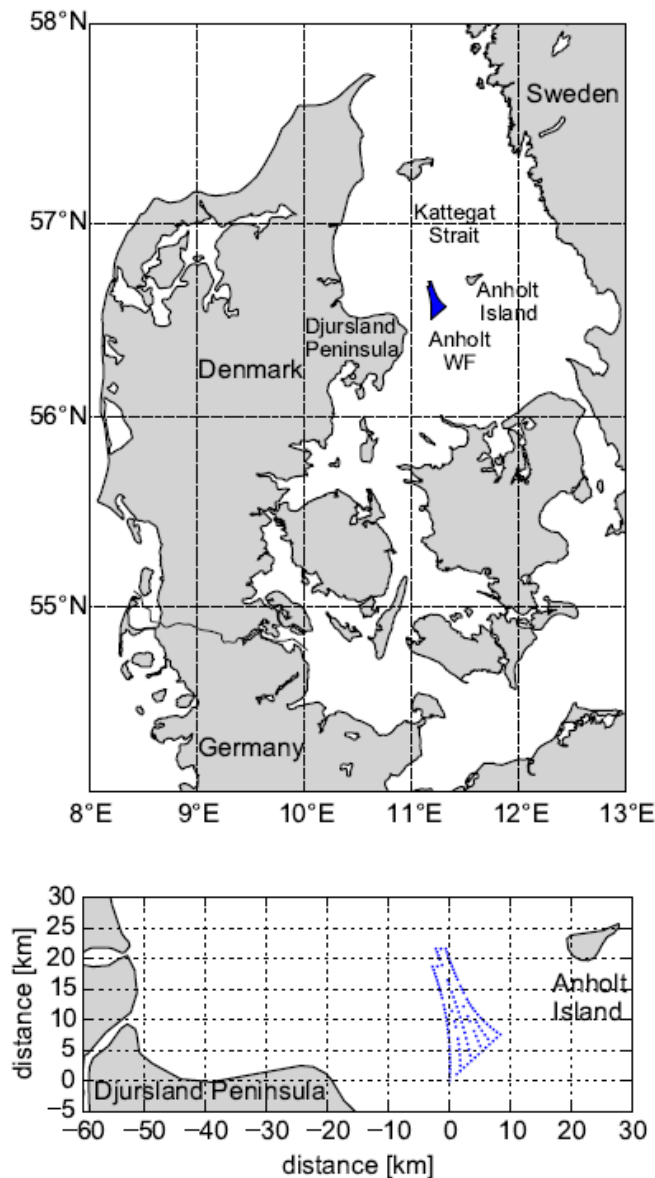
Sub-task:

How large is the coastal wind speed gradient?

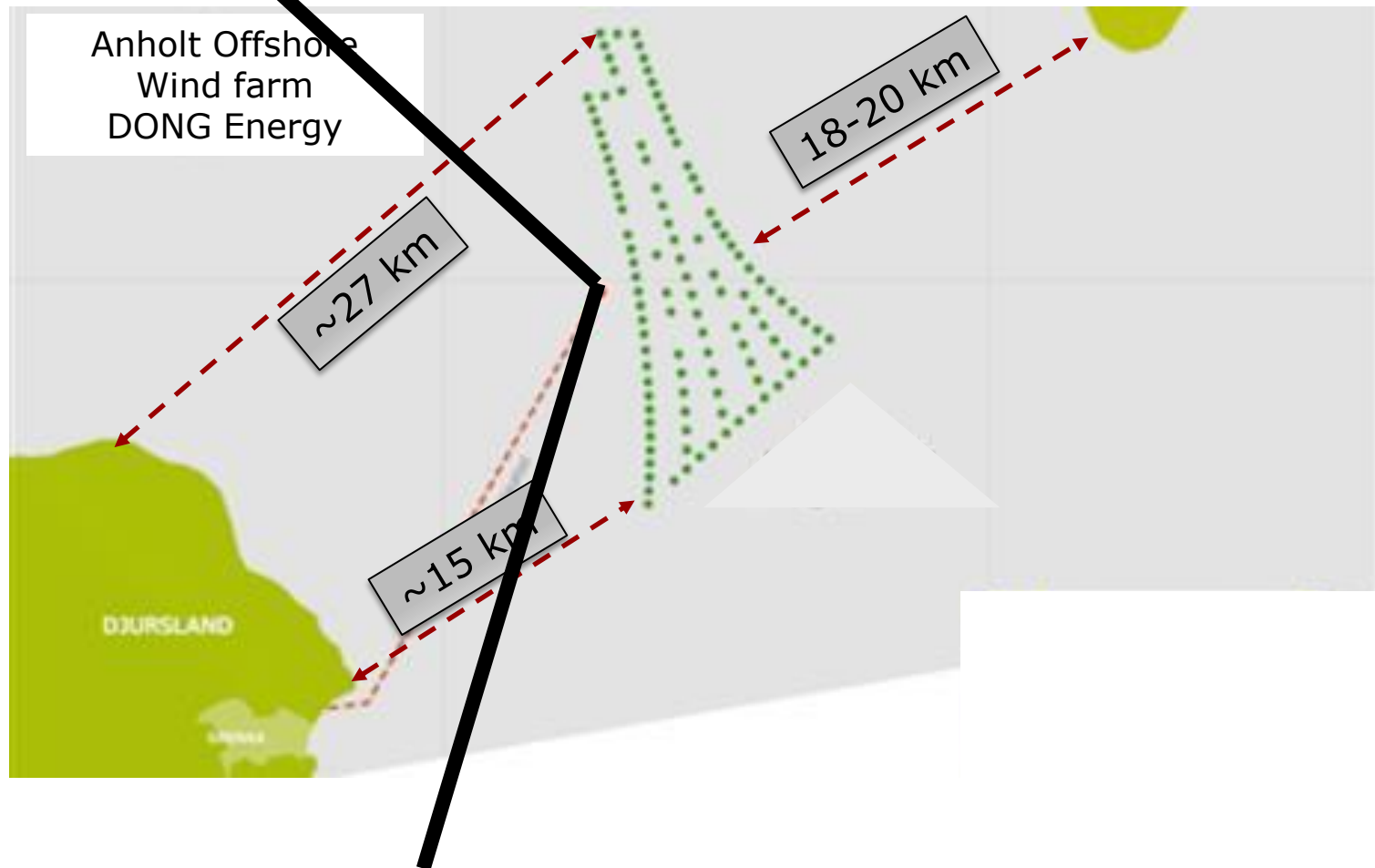
Data

- Supervisory control and data acquisition (SCADA)
- Satellite Synthetic Aperture Radar (SAR)
- Weather Research and Forecasting model (WRF)
- Reynolds-averaged Navier-Stoke model (RANS)

Location



Fetch and wind speed gradient

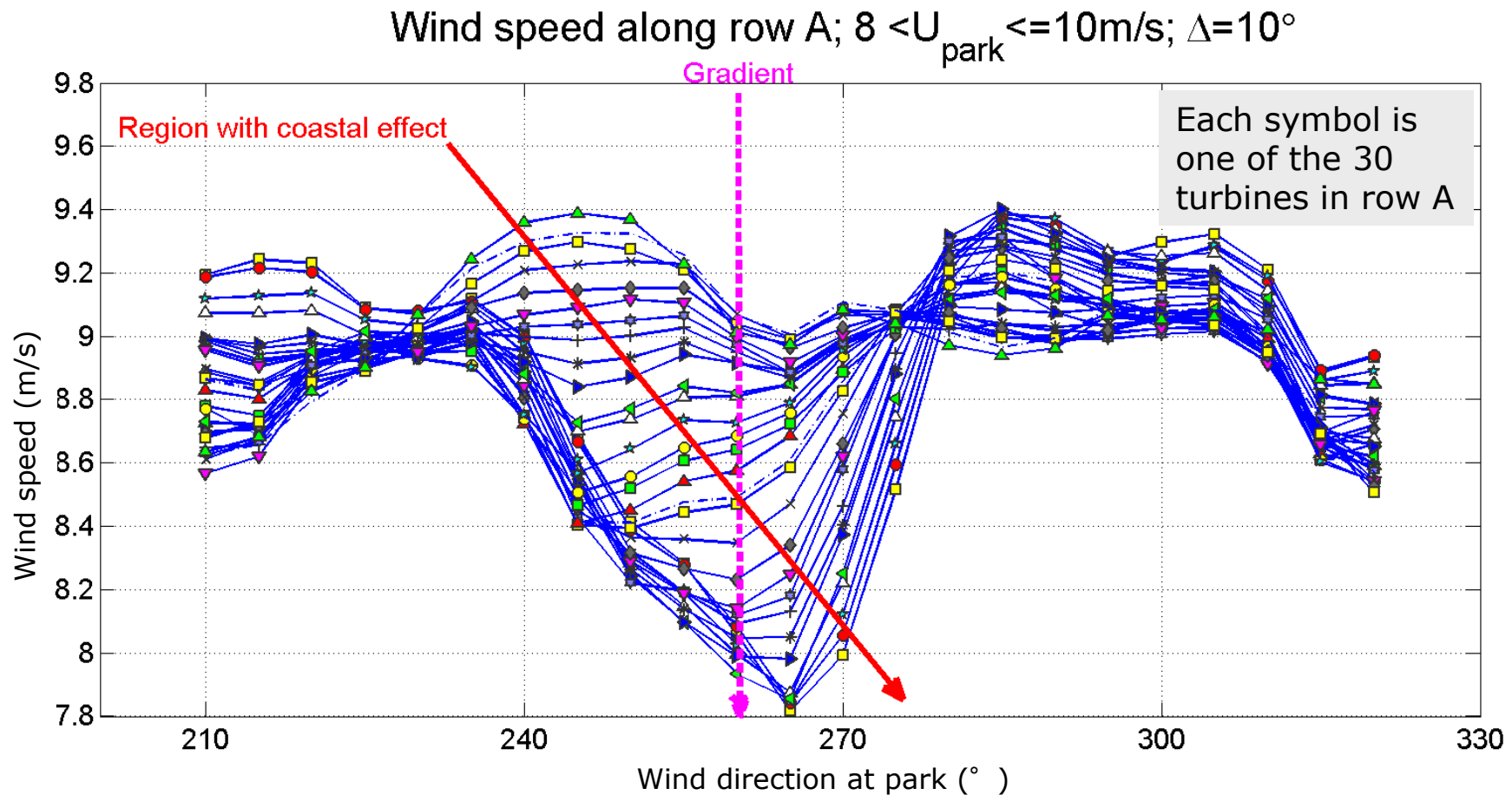


Coastal wind gradient investigation

SCADA

Wind speed interval 8 to 10 m/s

Westerly flow from 210 ° to 320 °

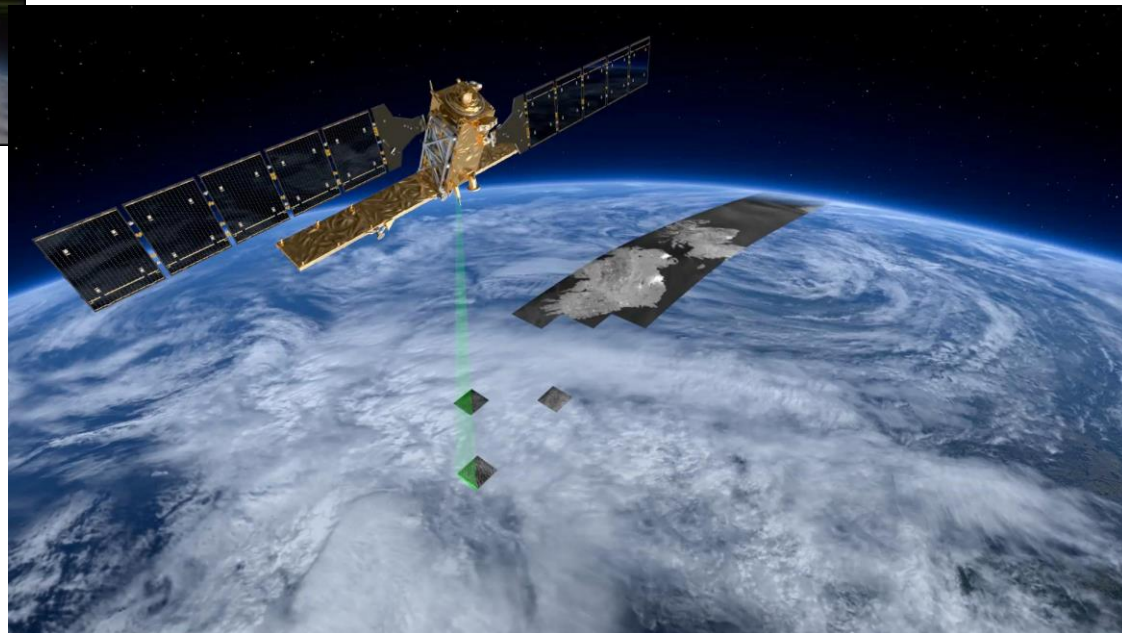


European satellites with SAR



Envisat
2002-2012

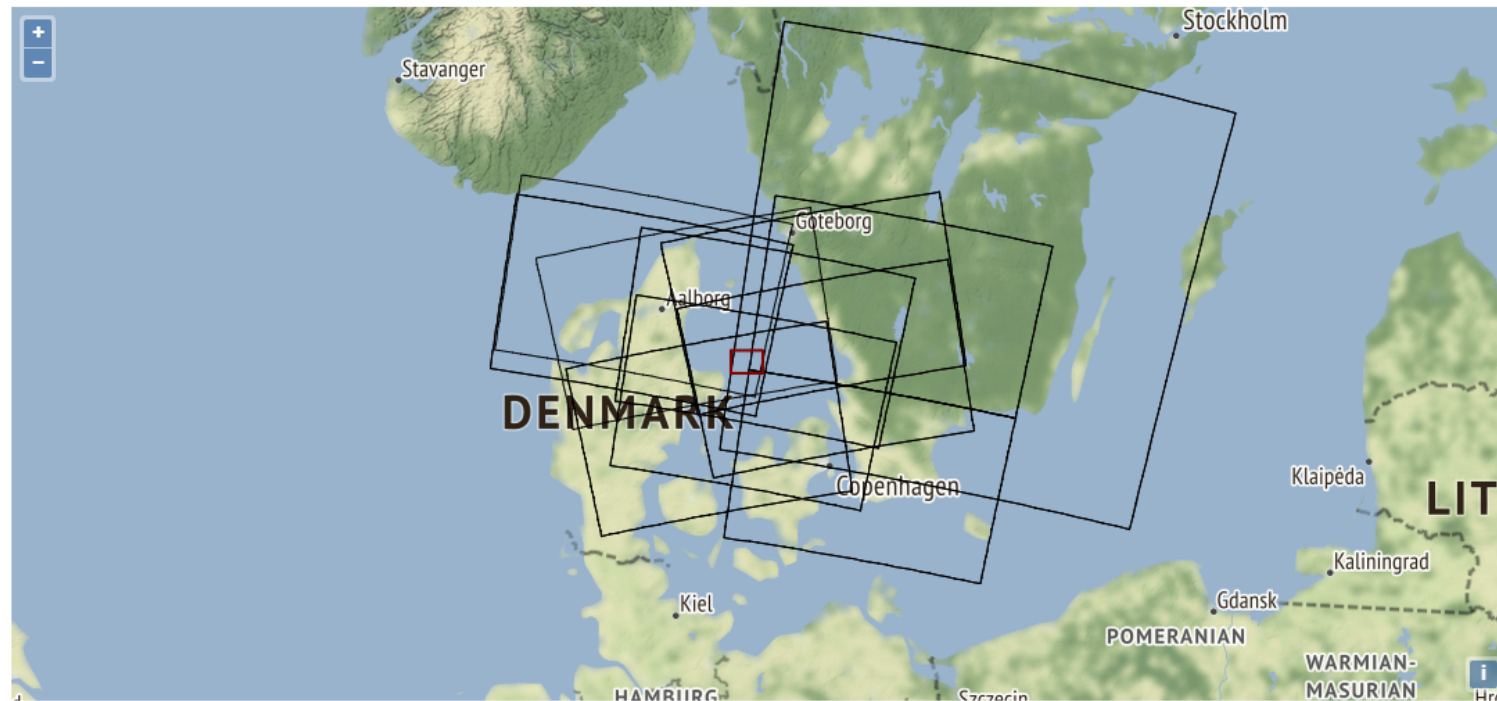
Sentinel-1a/b
2014/2016-present



SAR wind data archive

DATA STATION

Home Satellite winds



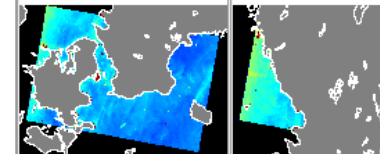
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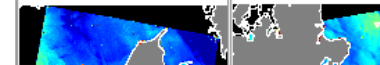
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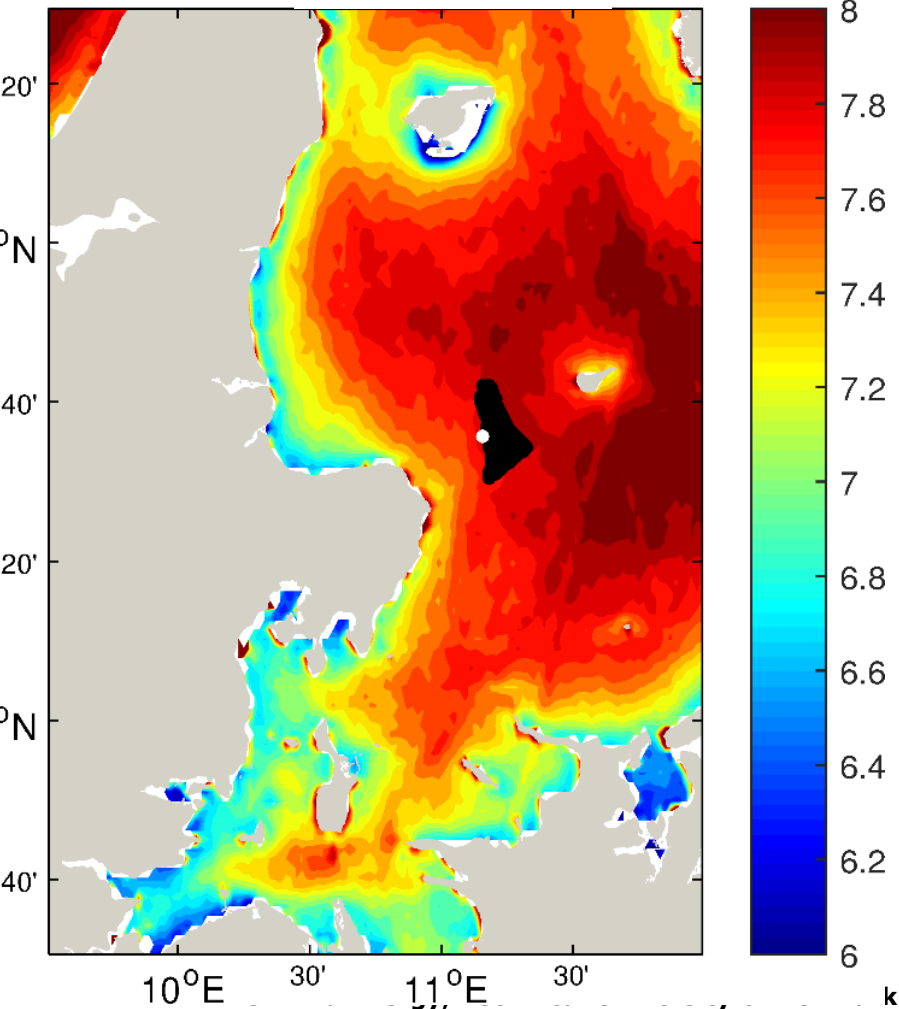
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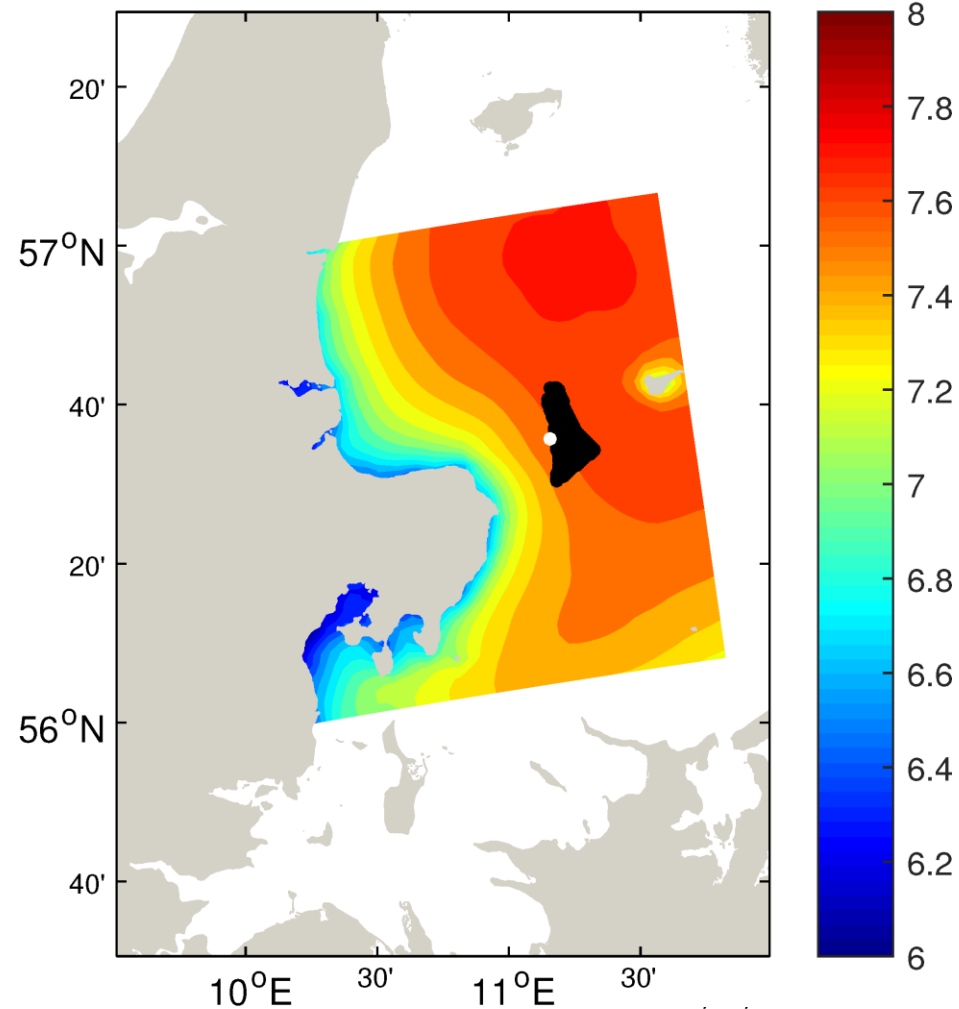
SAR and WRF (without wind farm)

Mean wind speed at 10 m

SAR – 2002-2012

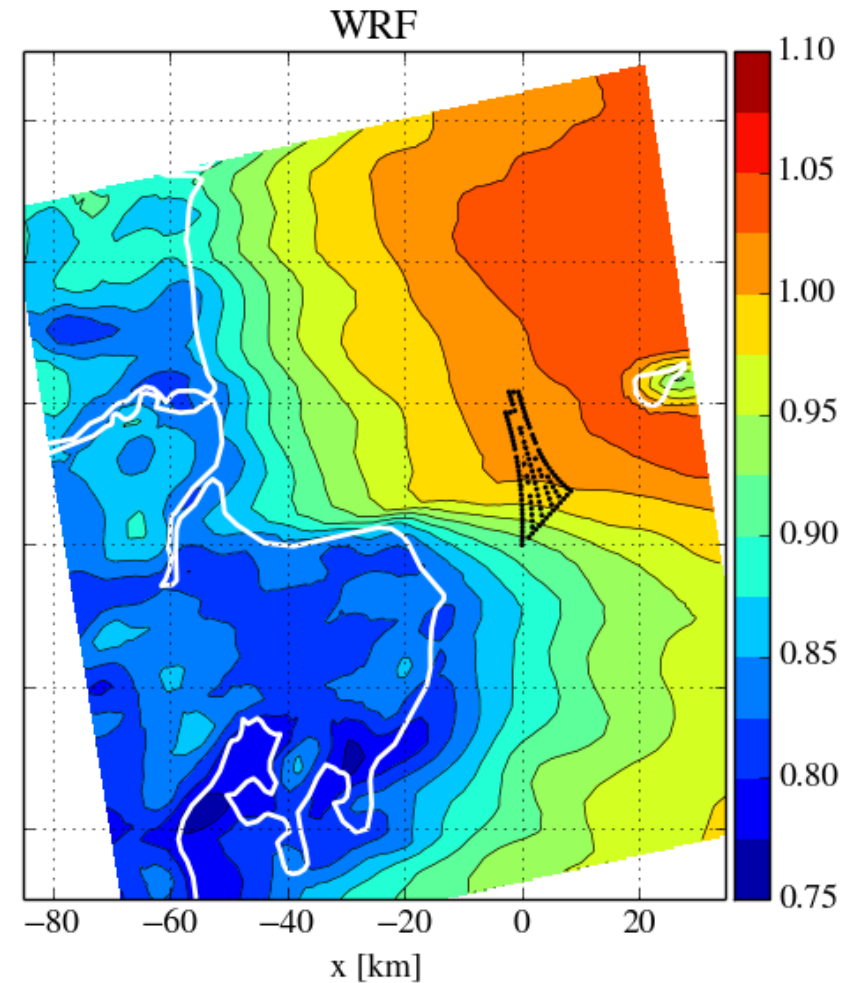
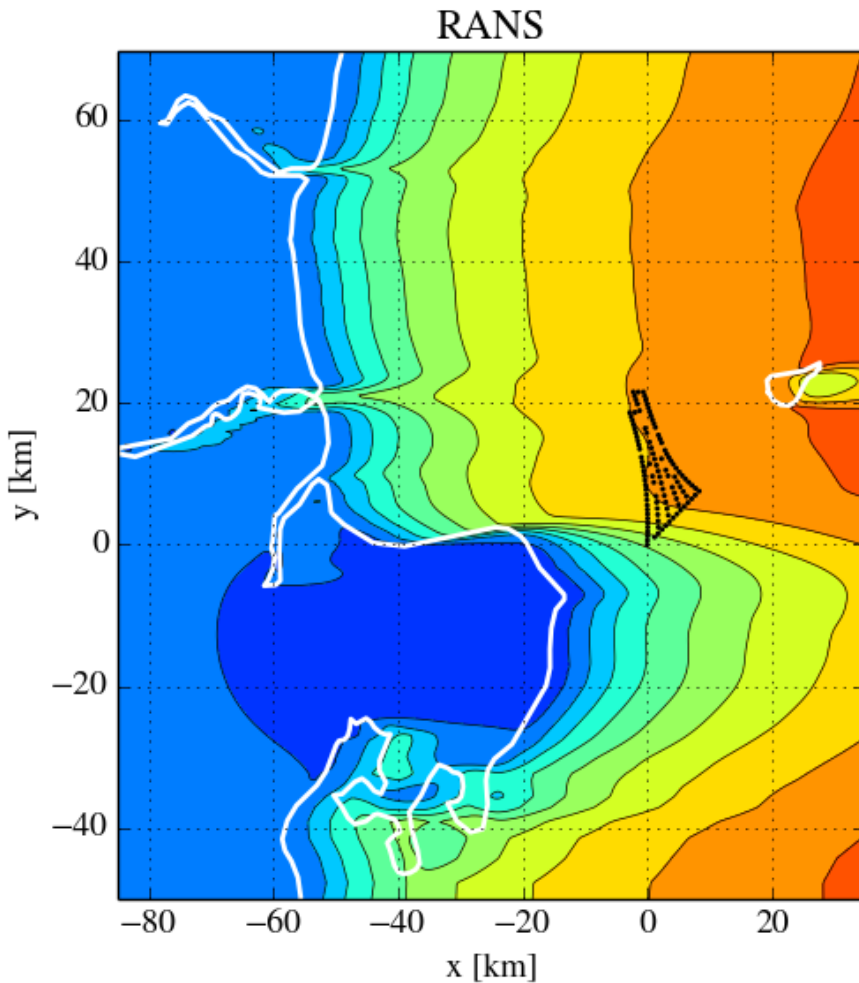


WRF – 2014



RANS and WRF (without wind farm)

Wind speed at hub-height for $270^\circ \pm 5^\circ$



Results from RANS

Animation 1:

Wind speed at hub-height from RANS without wind farm.

Animation 2:

Normalized wind turbine power from RANS and SCADA.

M. P. van der Laan, A. Pena, P. Volker, K. S. Hansen, N. N. Sørensen, S. Ott, C. B. Hasager.

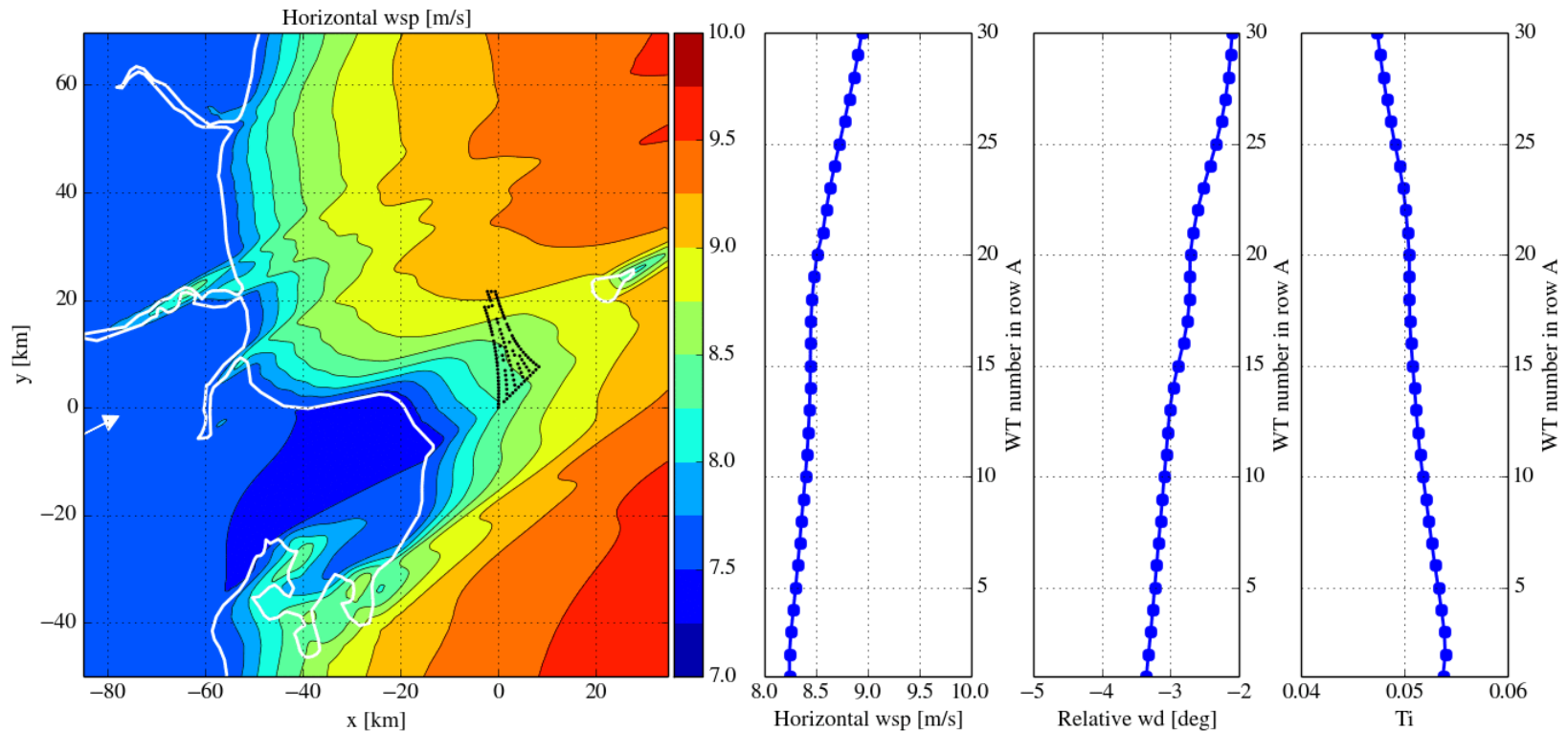
Challenges in simulating coastal effects on an offshore wind farm

IOP Visby wake conference 30 May - 1 June 2017 (in press)

RANS (without wind farm)

Wind speed at hub-height

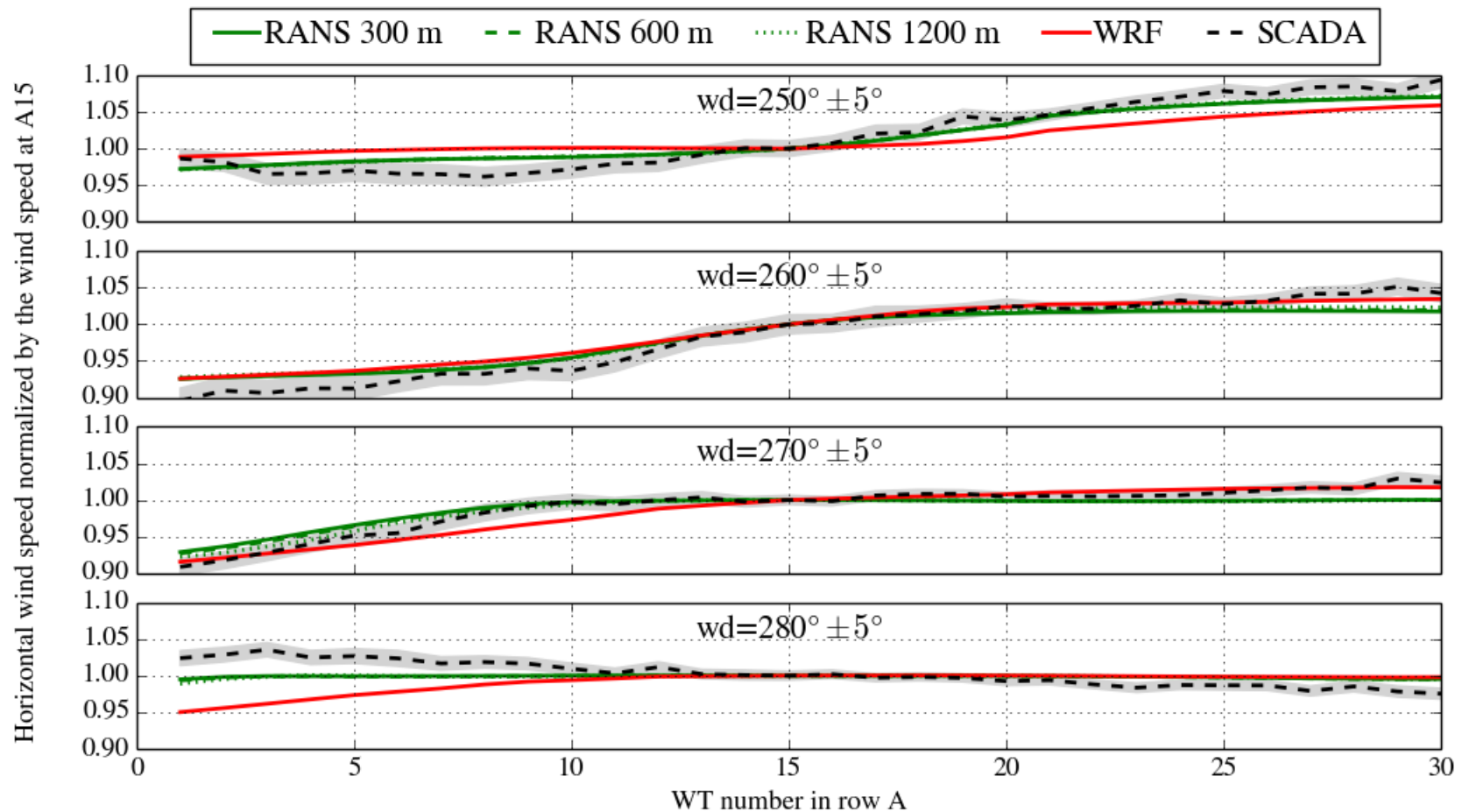
Influence of coast line on inflow conditions at hub height of Anholt WF, $w_d=245.0$



RANS, WRF and SCADA

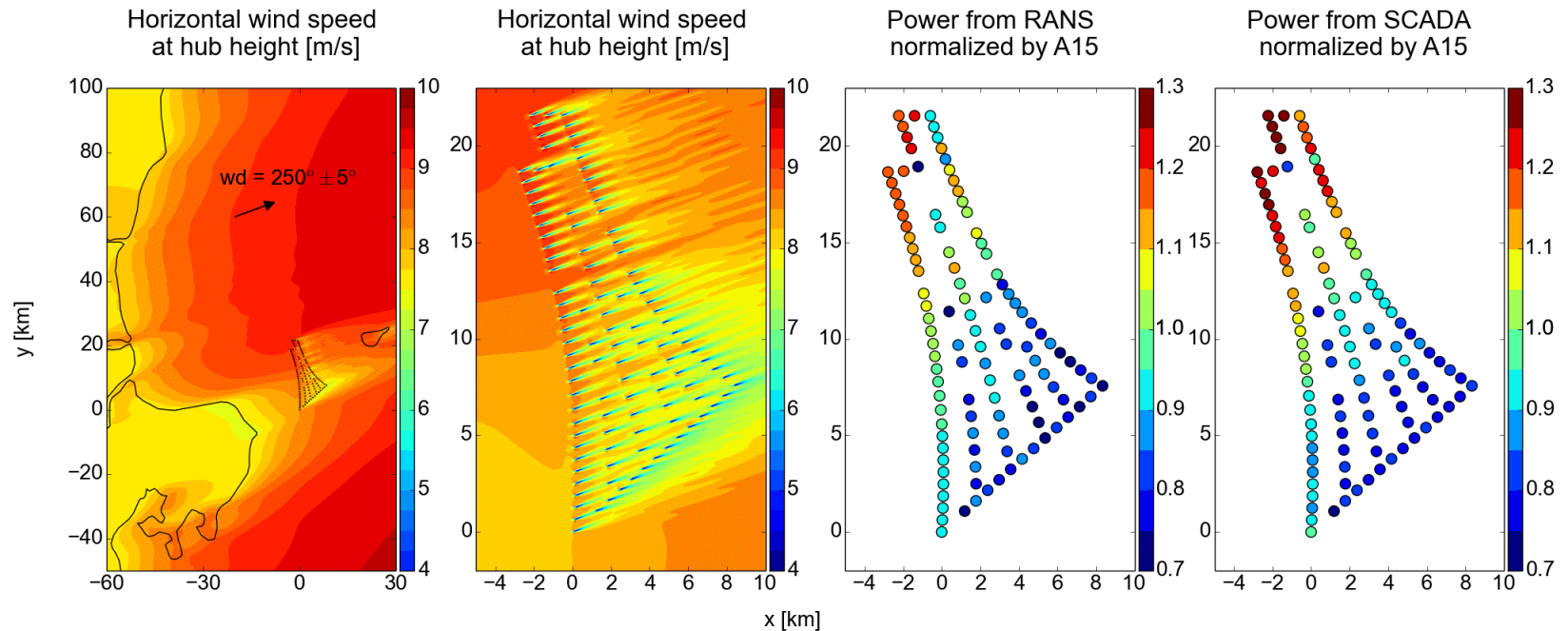
Wind speed at Row A

(turbines from south to north)

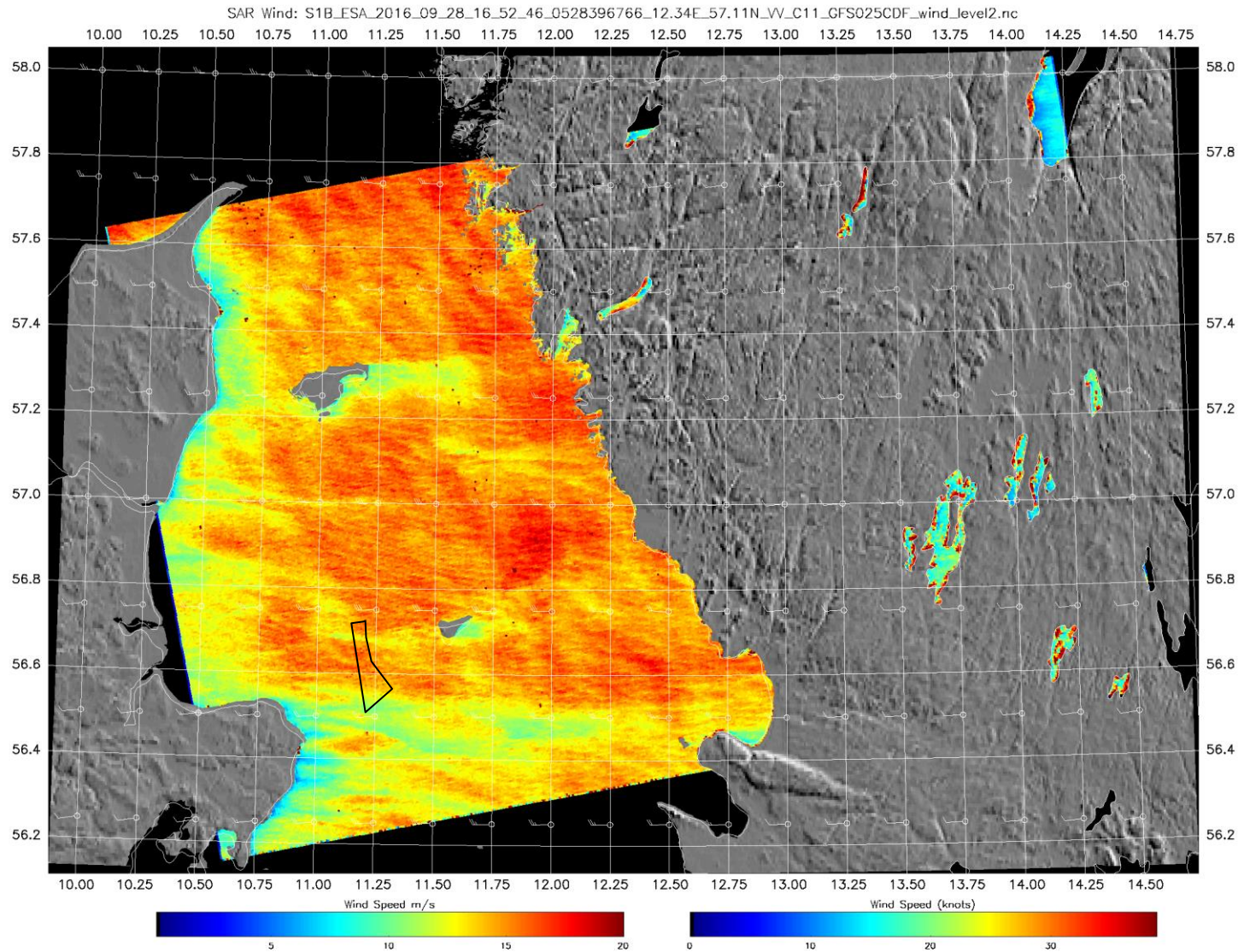


Wake investigation

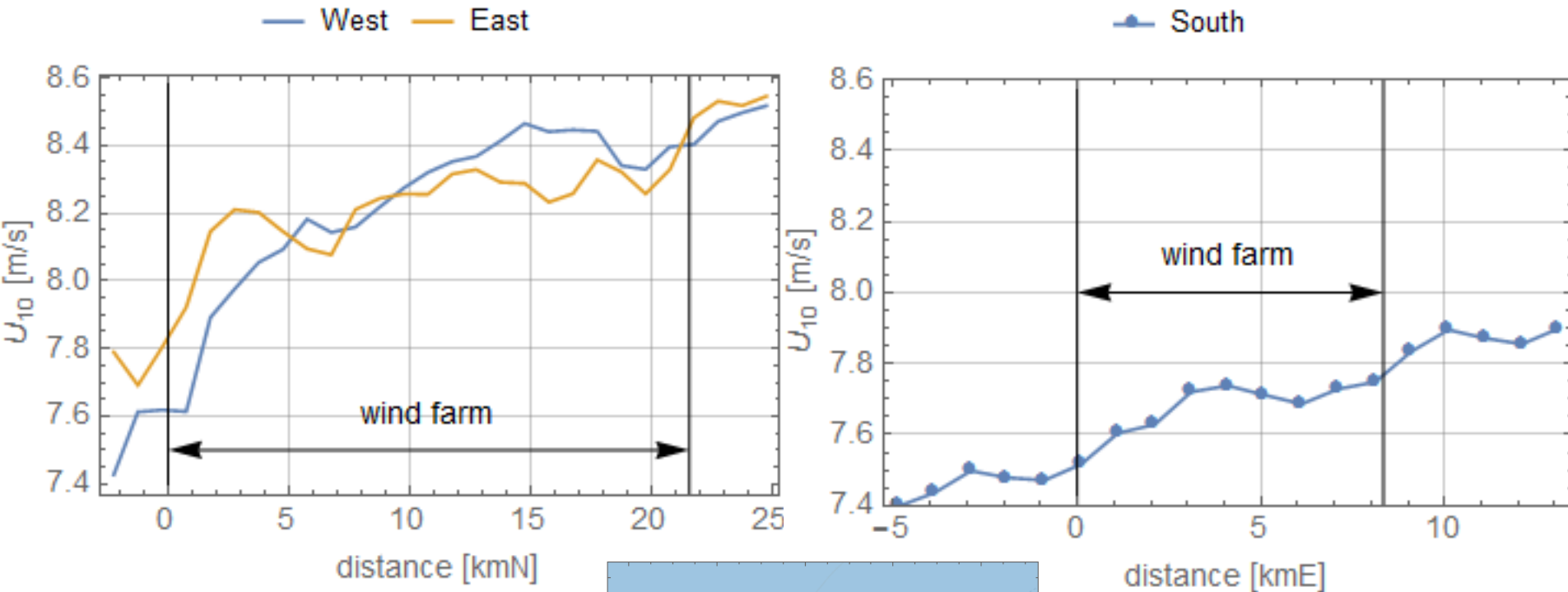
RANS and SCADA wind turbine power (normalized)



Wakes in SAR wind map



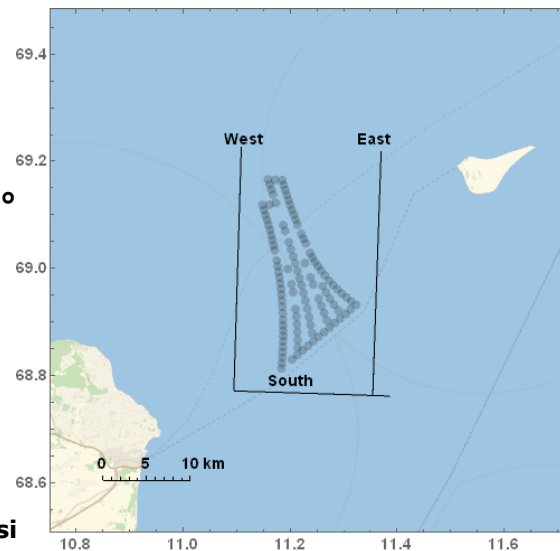
SAR-based mean wind speed at 10 m



Selection

30 Sentinel-1a/b scenes

Wind direction from 250° to 270°
taken from the GFS data



Conclusions

There is significant wind speed gradient at Anholt offshore wind farm in particular for westerly flow.

SCADA, WRF, RANS and SAR confirm the wind speed gradient.

Wind farm wake from RANS and SCADA for specific wind speed and direction compare well.

Satellite SAR analysis indicate far-field wind farm wake.

Acknowledgements

We thank DONG Energy and partners for the SCADA data.

Satellite SAR data are from ESA and Copernicus.